International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

A Study on Nanoparticles as a Promising Carrier for Loading Herbal Constituents

[1]Rahmathunnisa MK, [1]Afeefah Aboobacker KP, [1]Jishana CK, [1]ShahanaShirin KT,[1]Filda, [2*]Lubna TP, [3]Sirajudheen MK.

[1-3]Department of Pharmaceutics, Jamia SalafiyaPharmacy College, Pulikkal, Malappuram, Kerala.
Corresponding Author: Shahana Shirin KT, Department of Pharmaceutics,JamiaSalafiyaPharamacyCollege, Pulikkal, Malappuram,Kerala.

Date of Submission: 20-10-2024 Date of Acceptance: 30-10-2024

ABSTRACT
Nanoparticles are tiny particles with diameter between 1 to 100 nm they have unique physical, chemical and biological properties due to their small size. They have wide range of application especially for drug delivery, imaging etc in medicine and in cosmetics. When it comes to delivering herbal ingredients with better bioavailability, targeted administration, and increased therapeutic efficiency, nanoparticles have shown great promise. The herbal medication is encapsulated in nanocarriers to increase its therapeutic value, and nanotechnology has been developed to stimulate the activity of herbal medications on the target site.Based on their composition, dimensions, surfaces, and forms, nanoparticles are categorized into two main categories: organic and inorganic nanocarriers. By adjusting their dimensions or composition, these carriers'physiochemical properties can be fine-tuned. This can result in increased surface area, improved solubility, bioavailability, and easier precise drug targeting when used in herbal remedies.
The study comes to the conclusion that creating herbal medications in nanocarriers would be a promising guide for the development of core remedies and will serve as a promising suggestion for many pathological conditions. The study focuses on nanoparticles, herbal drug-loading techniques, herbal nano-formulations, and applications in various fields.
KEY WORDS: Nanoparticles, Herbal Constituents, Novel drug delivery system, Herbal nano formulation.

I. INTRODUCTION

Nanoparticles are extremely small particles that range in size from 1 to 100 nanometers (nm). They have unique properties compared to their bulk counterparts due to their small size, large surface area, and quantum effects. These properties make nanoparticles useful in a variety of fields, including medicine, electronics, energy, and materials science.

The increased surface area allows nanoparticles to be more reactive and efficient as catalysts in chemical reactions.Nanoparticles often have unique optical, thermal, and electrical properties that are not seen in bulk materials. Then, can be engineered to deliver drugs directly to targeted cells, reducing side effects and improving treatment efficacy.The small size of nanoparticles allows them to easily enter the human body, where they can interact with cells and potentially cause toxic effects.may persist in the environment and disrupt ecosystems if they are not biodegradable. [1]

The high cost may lead to unequal access to nanoparticle-based technologies, potentially widening the gap between developed and developing regions. The use of nanoparticles in human health, such as in drug delivery, raises ethical questions about their long-term impact on health and society.
Then the strengthening Materials,when added to materials like polymers, nanoparticles can significantly enhance their strength, durability, and thermal resistance.[2]

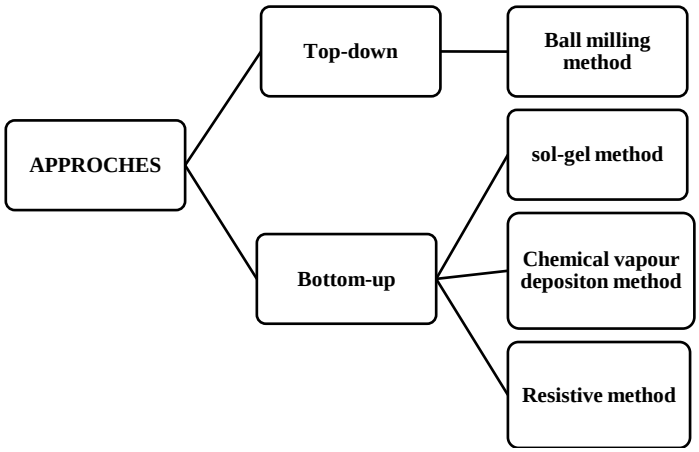
Types of Nanoparticles

1. Metallic Nanoparticles: Made from metals like gold, silver, or platinum, these are often used in electronics, medical imaging, and drug delivery.
2. Ceramic Nanoparticles: Composed of ceramics like titanium dioxide or silica, these are used in applications like catalysis, sensors, and environmental protection.
3. Polymeric Nanoparticles: Made from organic polymers, they are often used in drug delivery systems due to their ability to encapsulate drugs and release them in a controlled manner.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

4. Liposomes and Micelles: These are lipid-based nanoparticles commonly used for drug delivery.
5. Carbon-based Nanoparticles: Including fullerenes, carbon nanotubes, and graphene, these are used in electronics, materials science, and energy storage.[3]

Approaches of nanoparticles



Top-Down Approaches:

It is a physical process. In this, a large-scale object is progressively reduced in dimension. It consists of ultra-fine micro machining of materials using lithography, epitaxy, and etching. This method is time consuming and relatively costly.[4]

Bottom Down Approaches

This is a chemical process. In this, different materials and devices are constructed from molecular components of their own which do not require any external agent to assemble them. They chemically assemble themselves by recognising the molecules of their own type. This approach starts by collection and combination of atoms and molecules to build complex structures.[5]

Application

Nanoparticles can be engineered to deliver drugs directly to targeted cells or tissues. improving the efficiency of treatments and reducing side effects.

For example, liposomes and polymeric nanoparticles are used to deliver chemotherapy drugs directly to cancer cells.[6]

Nanoparticles have a wide range of applications across various fields, including: medicines, cosmetics, food and agriculture, biotechnology, pharmaceutical etc.

In medicine mainly used for:

Drug delivery: Targeted delivery of drugs, improved bioavailability, and reduced side effect
Imaging: Contrast agents for MRI, CT, and fluorescence imaging.
Diagnostics: Biosensors, lab-on-a-chip devices, and point-of-care diagnostics.
Therapeutics: Cancer treatment, gene therapy, and vaccine development.
In cosmetics:
Skincare: Improved delivery of active ingredients, enhanced skin penetration, and better stability.
Haircare: Hair growth promotion, color protection, and improved texture.
In food and agriculture:
Food packaging: Improved shelf life, reduced spoilage, and enhanced safety.
Agriculture: Precision farming, crop protection, and nutrient delivery.[7]
In biotechnology:
Gene delivery: Efficient delivery of genetic material for gene therapy.
Protein delivery: Targeted delivery of proteins for therapeutic applications.
In pharmaceuticals:
Pharmaceutical manufacturing: Enhanced process efficiency and product quality.
These applications leverage the unique properties of nanoparticles, such as their small size, high surface area, and ability to interact with biological systems.[8

DIFFERENT NANOPARTICLE LOADED HERBAL CONSTITUENTS

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

	Plant with family	Plant part used	Nanoparticle type	Method of preparation	Herbal constituents	Evaluation	Stability studies
Herbal Extract ofAllivum sativum (Garlic) Loaded Chitosan Nanoparticle[9]	Amarylli daceae	Bulb	Polymeric nanoparticle	There are many preparation methods that are employed, depending on the type of nanoparticle and the materials used. The conventional methods for producing different types of nanoparticles are listed here, with a focus on polymeric nanoparticles like lipid and chitosan nanoparticles since they are commonly used in drug delivery systems.such as the Ionic Gelation Method (using chitosan nanoparticles), the Emulsion-Solvent Evaporation Method, the Nanoprecipitation Method, and the Coacervatio	Alkaloids Terpenoids Flavanoids glycosides phenolicacids, tannins etc.	Characterization, drug release studies, stability testing,biocombatibility and toxicity studies,efficacy testing, quality testing.	After storing the adjusted formulation in a stability chamber for eight weeks, the synthesized nanoparticle stability investigations were conducted. The samples were examined for physical appearance at 0, 1, 2, and 8 weeks following the relevant period (ICH Q1A).

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				n Method, GelationMethod(Forchitosan nanoparticle),Emulsion-SolventEvaporationmethod,Nanoprecipitation,coacervation method.			
[10]Fabrication of Indigofera linifolia LeaveExtract-LoadedNanoparticles	Fabaceae	leaves	Polymeric nanoparticle	The following procedures are commonly included in the preparation process for nanoparticles loaded with Indigofera linifolia leaf extract. Plant Sample Collection Identification Crude Extract Preparation Preliminary Phytochemical Analysis of a Crude Extract of Indigofera Linifolia Determination of Total Phenolic Content (TPC) and Total Flavonoid Contents (TFC) HPLC-UV Analysis of	Flavanoids saponins tannins alkaloidal terpinoids glycosides	To guarantee the efficacy, stability, and safety of nanoparticles loaded with Indigofera linifolia leaf extract, a number of crucial actions must be taken during evaluation include Characterization of the Crude Extract HPLC-UV Analysis of the Crude Extract,GC–MS analyses were performed to get insight into the phytocon	Studies on the stability of nanoparticles containing Indigofera linifolia leaf extract are necessary to evaluate how well the formulation holds up over time in terms of both efficacy and integrity. Which include Physical Stability, Chemical Stability, Thermal Stability, pH Stability,Microbiological Stability.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				the Crude Extract		stituents of a volatile nature,FT IR Analysis of the Crude Extract and Fabricate d NPs.	
[12]Cardamom Extract-Loaded Gelatin Nanoparticles as Effective Targeted Drug Delivery System to Treat Glioblastom	Zingiberaceae	fruit (capsule)	gelatin nanoparticles	There are various techniques that can be used to create gelatin nanoparticles, especially for drug delivery applications such as loading with cardamom extract. The desolvation process is one that is frequently employed, The adulterant material was cleaned, and the fruits were then coarsely powdered using an electric grinder. After soaking 150 g of ground material in hot distilled water, it was left in a shaking	Cardamom (typically Elettaria cardamomum for green cardamom) contains a variety of bioactive compounds that contribute to its therapeutic properties. Flavonoids, Volatile oil,fixed oil, alkaloids, terpenoids.	In vitro (lab) and in vivo (animal or clinical) experiments are used to evaluate the efficacy, safety, and usefulness of gelatin nanoparticles, particularly those loaded with cardamom extract for targeted drug administration. That included UV-Vis spectrophotometry, X-Ray diffraction (XRD), Fourier transform infrared	An essential component in assessing the safety, effectiveness, and shelf life of gelatin nanoparticles infused with cardamom extract is a stability study. It entails putting the nanoparticles through a variety of environmental tests to see how variables like humidity, temperature, and exposure to light alter the particles' chemical and physical characteristics over time.

				incubator (GFL 3031) set to 25°C and 40 rpm for the duration of the night. After filtering it through a cloth, we left it in the shaking incubator for another night at 25°C and 40 rpm. To remove the larger particles, we centrifuged the extract for 10 minutes at 4500 rpm using a universal 320R hettichzentrifugen. Ultimately, the extract was freeze-dried to provide the extract's cream powder.		spectroscopy (FTIR), Differential scanning calorimetry (DSC), SEM observation, Particle size analysis, Zeta potential, entrapment efficiency.	
[13]Preparation, physical properties, and evaluation of antioxidant capacity of aqueous grape	Vitaceae	Grape skin, grape seed	chitosan-TPP nanoparticles.	The grapes were first dried for 30 minutes at 50°C in an oven. After that, they were ground to make a powder, which was subsequentl	The herbal ingredients in aqueous grape extract, which are incorporated into chitosan-TPP nanoparticles, largely	Assessing the physical characteristics, stability, and antioxidant capacity of the nanoparti	To make sure that chitosan-TPP nanoparticles containing aqueous grape extract retain their effectiveness, safety,

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

extract loaded in chitosan-TPP nanoparticles				y put through a mesh (No. 35). The resulting powder was then dissolved in deionized water and subjected to 35 kHz waves for 15 minutes at 55°C in an ultrasonic bath (UP200H, Germany). Next, contaminants were taken out of the extract by filtering it with Whatman filterpaper No. 5. After that, the extracted material was kept out of the light and moisture in a sealed container.	include numerous bioactive chemicals present in grapes.organic acid, polyphenols, flavonoids, tannins, and vitamins.	cles is one way to determine how efficient aqueous grape extract loaded in chitosan-TPP nanoparticles is. This is a thorough overview of the assessment procedure: Particle size and polydispersity index, Zeta potential, Fourier-transform infrared (FTIR)spectrometry.	and quality over time, stability tests are crucial.
PeppermintExtract Loaded Gelatin Nanoparticles forDiabetic Wounds Healing: Characterization, In Vitro, and InVivo Studies.[14]	Lamiaceae	Peppermint leaves	Gelatin nanoparticles	Six liters of solvent were used to extract 1000 g of dried peppermint leaves three times over in a constant 72-hour period using the maceration method. The	Peppermint (Mentha piperita) contains several active herbal constituents that contribute to its therapeutic and medicinal properties.	Microscopic Analysis, TEM, FTIR Analysis, TGA Analysis, Mechanical Properties,Histomorphometric Analysis.	To make sure that peppermint extract-loaded gelatin nanoparticles continue to be high-quality, effective, and safe over time, stability tests are

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				leaves were pulverized and extracted using ethanol/distilled water (80/20) at room temperature. The extracted materials were mixed, sieved, and vacuum-dried at 40 °C. and include: Preparation of Crosslinked Gelatin Extract Nanoparticle, Preparation of Nanofibers.	Like, flavonoids, phenolic compound, tannins, saponins.		crucial.
[15] Herbal extract of Curcumin-loaded into PLGA nanoparticles	Turmeric ,zingiberaceae	rhizomes	PLGA poly(lactic-co-glycolic)acid	The curcumin-loaded PLGA nanoparticles were prepared by the nanoprecipitation method.PLGA and curcumin were dissolved in acetonitrile and dropped into the stirred surfactant aqueous phase at room temperature	curcumin,phenol, alkaloid, tannin, and saponin.	By using FESEM and DLS, the resulting particles' morphology was verified. The generated particles are spherical and aggregated, as the FESEM image demonstrates. DLS verified the	Research shows that these nanoparticles exhibit physical stability, with no significant change in particle size, shape, or morphology over three months, and chemical stability, retaining 85-90% of curcumin over six months with minimal degradation.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				by using a syringe. The suspension was stirred for 30 min and the evaporation under reduced pressure was used to remove the organic solvent and to concentrate the suspension.		production of spherical particles in the turmeric nanosize range and show. It was also determined how well the curcumin-loaded Erick nanoparticles inhibited the growth of PLAGA nanoparticles.	Biological stability is also maintained, with consistent antioxidant and anti-inflammatory activity over two months. Storage conditions can impact stability, with room temperature storage stable for three months, refrigeration for six months, and freezing for twelve months.
[17]Solanum nigrum L. leaf extract-loaded sodium alginate nanoparticles	Solanaceae	Leaves	Sodium Alginate Nanoparticles	The maceration method has been used to prepare the alcoholic extract of s. nigrumL leaves. Firstly 100g of s. nigrum L leaves were collected from the areas around mashhad ,iran, the leaves were well dried powdered and soaked in ethanol 70% for 48 hr then this	Alkaloids, flavonoids, phenols,saponins,glycoside, essential oil.	Particle size,in vitro studies, in vivo studies,biocombactibility.	Stability studies for Solanum nigrum L. leaf extract-loaded sodium alginate nanoparticles involve a series of evaluations to ensure that the formulation maintains its physical, chemical, and functional integrity over time.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				mixture was passed through paper filter. After removing the ethanol the extract was placed in a freeze dryer and 49g of dried extract leaves were obtained.			
Formulation of Neem oil-loaded solid lipid nanoparticles and evaluation of its anti-Toxoplasma activity[18]	Meliaceae	seeds	Solid Lipid Nanoparticles	In this study, lipids such as cholesterol and surfactants like lecithin and Tween 80 were employed. NeO-SLN preparation was evaluated using the MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay. The vero cell wells that were not treated and the one that received 150 mg/mL of clindamycin were identified as the positive and negative controls,	Azadirachtin,Nimbin, Nimbidin, Salannin, Gedunin, Quercetin, Triterpenoids.	Fabrication of the NeO-SLNs, electron microscopy, and particle size analysis, Entrapment efciency, FTIR-spectra (compatibility with excipients, zeta potential, In vitro release and release kinetic studies.	Stability studies are crucial in assessing the shelf life, safety, and efficacy of neem oil-loaded solid lipid nanoparticles (SLNs). These studies determine how the formulation behaves under various environmental conditions over time.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				respectively. After 24 hours, the supernatant was gathered, and the MTT solution (5 mg/mL) was immediately added to the wells at a ratio of 15% (v/v). The plate was then incubated for an additional 4 hours. at 37°C in 5% CO2 before 150µL/well of dimethyl sulfoxide was added to end the trials. To evaluate the results, the plate was read. an enzyme-linked immunosorbent assay (ELISA) microplate reader operating at 570 nm.			
[19]Mangifera indica L. Extract-Loaded Green Nanoparticles	Anacardiaceae	Leaves	Green nanoparticles	Mango waste (peels and kernels) was dried into a fine powder and extracted using pure methanol (10:1, v/w) by stirring.	Polyphenols,flavanoids, tannins,saponins.	Preparation of Extract,Identification of Compounds in M. indica Peel and Kernel Extract,A	Measure the particle size and polydispersity index (PDI) at regular intervals using Dynamic Light

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				The extract was refined and solvent evaporation was done using a rotary evaporator following stirring. After drying, the extract was stored at -4 °C. Equation was used to determine the % yield.		tomic Absorption Spectroscopy,Fourier-Transform Infrared,Spectroscopy (FTIR).	Scattering (DLS). Significant changes in size or PDI could indicate aggregation or instability, Oxidative Stability, Thermal Stability.
[20]Herbal extract of guava leaf (Psidium guajava L.) loaded Silk nanoparticle	Myrtaceae	leaves	silk nanoparticle	Fresh guava leaves were collected, allowed to dry at room temperature, and ground into a fine powder. 300 g of the powder was then extracted with 1 L of ethanol using the maceration method. After 24 hours, the extract was collected, and the remaining solid matter was extracted twice more using ethanol. The extracts were then mixed, filtered, and	Flavonoids ,tannins, phenolic compounds,saponins, essential oils	Chemical analysis ,antioxidant activity ,anti microbial testing , bioavailability	Accelerated Stability Testing ,Long-Term Stability Testing ,Chemical Stability ,Physical Stability, microbial stability.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 5 Sep - Oct 2024, pp: 1072-1085 www.ijprajournal.com ISSN: 2456-4494

				solvent evaporated using an until they were semi-solid. They were then stored at 4 °C for further investigation.			

II. CONCLUSION

In summary, nanoparticles have shown tremendous promise as carriers for loading herbal constituents, offering improved bioavailability, targeted delivery, and enhanced therapeutic efficacy. The versatility of nanoparticles allows for tailored design and modification to suit specific herbal extracts, maximizing their potential benefits. Our study demonstrates the potential of nanoparticles to revolutionize the field of herbal medicine, enabling more effective and efficient delivery of herbal constituents. Future research should focus on further optimizing nanoparticle design, exploring new herbal extracts, and conducting in-depth in vivo studies to fully realize the potential of nanoparticles as carriers for herbal constituents. Ultimately, this technology has the potential to unlock the full therapeutic potential of herbal medicine, providing new hope for the treatment of various diseases and improving human health.

REFERENCE

[1]. Prow, T. W., Grice, J. E., Lin, L. L., Faye, R., Butler, M., Becker, W., Wurm, E. M., Yoong, C., Robertson, T. A., Soyer, H. P., & Roberts, M. S. (2011). Nanoparticles and microparticles for skin drug delivery. Advanced Drug Delivery Reviews, 63(6), 470–491.https://doi.org/10.1016/j.addr.2011.01.012

[2]. Laurent S, Forge D, Port M, Roch A, Robic C, Vander Elst L, et al. Magnetic iron oxide nanoparticles: Synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications**.** Chem Rev**.** 2008;108(6):2064-110.

[3]. Dubchak S., Ogar A., Mietelski J.W. and Turnau K., Influence of silver and tianium nanoparticles on arbuscular mycorhiza colonization and acumulation of radiocaesium in Helianthus anus, Span. J. Agric. Res., 8(1), 103-108, (2010).

[4]. S. A. Maier, M. L. Brongersma, P. G. Kik, S. Meltzer, A. A. G. Requicha, H. A. Atwater, Adv. Mater. 2001, 13, 1501.

[5]. Molecules | Free Full-Text | The History of Nanoscience and Nanotechnology: From Chemical–Physical Applications to Nanomedicine. Available online: https://www.mdpi.com/1420-3049/25/1/112 (accessed on 30 October 2022).

[6]. Ming, W.; Jiang, Z.; Luo, G.; Xu, Y.; He, W.; Xie, Z.; Shen, D.; Li, L. Progress in Transparent Nano-Ceramics and Their Potential Applications. Nanomaterials 2022, 12, 1491.

[7]. B.B. Aggarwal, M.E. Van Kuiken, et al.Molecular targets of nutraceuticals derived from dietary spices: potential role in suppression of inflammation and tumorigenesisExp. Biol. Med. (Maywood), 234 (8) (2009), pp. 825-849.

[8]. Revia, R. A., & Zhang, M. (2016). Magnetite nanoparticles for cancer diagnosis, treatment, and treatment monitoring: recent advances. Materials Today, 19(3), 157–168. https://doi.org/10.1016/j.mattod.2015.08.022

[9]. Slman Dhuha Kadhem, Dhyea Raghad Jalill Abdul, N Ahmed. Abd, Biosynthesis of zinc oxide nanoparticles by hot aqueous extract of Allium sativum plants, J. Pharm. Sci. & Res,2018; 10(6):1590- 1596.

[10]. Suryanti, V.; Marliyana, S.D.; Putri, H.E. Effect of Germination on Antioxidant Activity, Total Phenolics, β-Carotene,

Ascorbic Acid and α-Tocopherol Contents of Lead Tree Sprouts (Leucaena leucocephala (Lmk.) de Wit). Int. Food Res. J. 2016, 23, 167–172.

[11]. Hamid, A.A.; Aiyelaagbe, O.O.; Usman, L.A.; Ameen, O.M.; Lawal, A. Antioxidants: Its Medicinal and Pharmacological Applications. Afr. J. Pure Appl. Chem. 2010, 4, 142–151.

[12]. M. Azami, F. Moztarzadeh, M. Tahriri, Preparation, characterization and mechanical properties of controlled porous gelatin/hydroxyapatite nanocomposite through layer solvent casting combined with freeze-drying and lamination techniques, Journal of Porous Materials 17(3) (2010) 313-320.

[13]. Crucho C. I. C. and Barros M. T., Formulation of functionalized PLGA polymeric nanoparticles for targeted drug delivery, Polymer. (2015) 68, 41–46, https://doi.org/10.1016/j.polymer.2015.04.083, 2-s2.0-84930008274.

[14]. Saeidnia S., Gohari A. R., Yassa N., and Shafiee A., Composition of the volatile oil of Achillea conferta DC. from Iran, DARU Journal of Pharmaceutical Sciences. (2005) 13, 34–36.

[15]. Sahu, A., Bora, U., &Kasoju, N. (2008). Curcumin-loaded nanoparticles: a novel strategy for enhancing its bioavailability and anti-cancer potential. Journal of Nanobiotechnology, 6(1), 1-10.

[16]. Yallapu, M. M., Jaggi, M., & Chauhan, S. C. (2012). Polymeric nanoparticle formulations for curcumin delivery: a review. Molecular Pharmaceutics, 7(3), 775-793.

[17]. Sharma, S., Tiwari, S., Gupta, P., & Pandey, R. (2015). "Characterization and evaluation of herbal drug-loaded sodium alginate nanoparticles for ulcerative colitis." Journal of Drug Delivery Science and Technology, 29, 88-99.

[18]. Sharma, S., Rajak, S., & Sharma, R. K. (2018). "Neem oil and its nanoformulations: A comprehensive review on its uses in modern medicine." International Journal of Nanomedicine, 13, 2107-2125.

[19]. Khan, Y., Khan, M. I., Ullah, N., & Khan, M. N. (2022). "Application of Mangifera indica L. (mango) seed extract in the synthesis of biocompatible gold nanoparticles." Journal of Nanoscience and Nanotechnology, 22(3), 1844-1853.

[20]. Patel, S. D., Patel, A. N., & Patel, K. K. (2022). "Silk fibroin nanoparticles as a novel carrier for plant extract: Preparation, characterization, and biological applications." Journal of Nanoparticle Research, 24(4), 1-13.